

Adolescence: A Metamorphosis

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metamorphosis, n. [T]he process of transformation from an immature form to a different adult form...

Oxford English Dictionary Online¹

As a physician who has provided care to adolescents for 25 years and, more recently, as the father of an adolescent, I continue to marvel at the physical, cognitive, social, and emotional changes that take place during the period that lies between childhood and adulthood. Truly, there is a metamorphosis—a transformation from an individual who lives in the moment and is reliant entirely on parents, to one who is physically and cognitively capable of thriving independently. What characterizes this period, and what are the implications of this transition?

A Developing Body

The physical changes that take place during adolescence are striking. The growth spurt that begins at around the ages of 9.5 years in girls and 11.5 years in boys contributes 20% of one's adult height and 50% of one's ideal adult weight. In the year of most-rapid growth—at age 11.5 years in girls and 13.5 years in boys—the average girl will grow about 3.5 inches and the average boy 4 inches.² At no time beyond infancy and early childhood will one grow at a more rapid pace. During adolescence, body composition changes with increases in bone mineral density (40% of peak bone mineral density is achieved during this time) and muscle mass (which increases by 100% in boys and 50% in girls).^{2,3}

Of particular note are the physical changes associated with puberty. Beginning at around 6 years of age, the adrenal glands begin to increase production of androgens that ultimately will be responsible for the appearance of hair on the face, chest, axillae, and pubic area, and for the onset of body odor. In girls, the usual first sign of puberty is the onset of breast development (ie, thelarche) that reflects ovarian estrogen production. In the United States, thelarche typically occurs at the ages of 9 years in African American girls and 10 years in white girls. Approximately 2 years after the onset of breast development, between the ages of 9 and 15 years, menarche occurs. For boys, puberty begins at the age of approximately 9.5 years for African Americans and 10 years for whites with an increase in the size of the testes. Over the succeeding 3 years, there are increases in the size of the testes and phallus and the amount of sexual hair.

A Developing Mind

Accompanying the physical changes of adolescence is a process of psychosocial and cognitive maturation. A child is dependent on parents for physical and emotional support. Thought processes are concrete and related to past experiences, and peer relationships are not based on shared interests or values. In the span of a decade or more, however, most individuals are able to think abstractly (allowing them to envision the consequences of their actions), have developed a personal identity and sense of morality, and are self-sufficient and able to thrive independently.

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Psychosocial development during adolescence occurs as a continuum but often is separated into early (ages 10-13 years), middle (ages 14-16 years), and late (ages 17-21 years) stages. During early adolescence, individuals are keenly aware of and often self-conscious about the many physical changes taking place and are concerned with how others see them. The desire for autonomy becomes apparent and often there is less interest in family activities. Relationships with

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peers take on increasing importance, and there is a tendency to conform to the group's norms with respect to interests and style of dress. It is during this time that the desire to belong to a group places one at risk for experimentation with drugs or alcohol.^{4,5}

By middle adolescence, most teenagers have become comfortable with their bodies. They begin to think abstractly, comparing the actual with the possible, at times finding the former wanting. Parents may find this a frustrating time, as their position of authority and prominence appears less secure in the face of adolescent questioning. However, abstract thinking is essential. It allows the adolescent to see himself or herself in different roles, a major step toward identity formation and independence. Although the ability to think abstractly has begun, during this time adolescents have a sense of invincibility and often do not fully appreciate the consequences of their actions. This, coupled with ongoing peer pressure, increases the likelihood of participating in behaviors that pose a risk to their health, such as substance use and involvement in sexual relationships.^{4,5}

Late in adolescence, most individuals have formed an identity and have the ability to think abstractly and delay gratification. For the most part, the struggle for autonomy has been resolved, and the adolescent may be able once again to appreciate his parents' opinions and values. Mark Twain is said to have observed this process of renewed understanding when he wrote, "When I was a boy of 14, my father was so ignorant I could hardly stand to have the old man around. But when I got to be 21, I was astonished at how much the old man had learned in seven years."⁶

A Work in Progress

Traditionally, it has been stated that adolescence is complete by 21 years of age. However, there is compelling evidence that, despite achieving physical and intellectual maturity by this age, the brain continues to develop late into the third decade. Recognizing this may help explain adolescent behavior and suggests that we may need to rethink the guidance and support we provide them.

As health care professionals will recall, the brain is composed of gray and white matter. Gray matter contains nerve cell bodies that process and route information. White matter is composed of nerve cell extensions (ie, axons) that convey information from one area of the brain to another. Each new experience that we encounter results in new connections between nerve cells (ie, neurons). By the end of adolescence, the brain contains more than 10 billion neurons that form some 100 trillion connections with one another and 100 billion support cells.⁷ The result is an enhanced capacity for learning, reasoning, and problem solving.

The brain is a dynamic organ that undergoes remarkable changes. Studies employing sequential magnetic resonance imaging (MRI) demonstrate that during childhood gray matter increases greatly, presumably enhancing the capacity for learning.⁸ Information that is used regularly is retained; that

which is unimportant or used infrequently ultimately is discarded through a process called pruning, in which a loss of cells or cell connections occurs. As a result of pruning, adolescents may lose up to 15% of synaptic connections each year, compared with 1% to 2% annually for adults.⁷ Pruning continues into the third decade of life, resulting in greater efficiency of information processing. At the same time, the axons that connect cells are being encased in myelin. This fatty insulation increases the speed of impulse transmission 100-fold and, like pruning, is not complete until the third decade. As it turns out, different areas of the brain mature at different rates. For example, the limbic system, responsible for impulsiveness and sensation seeking, develops before the lateral prefrontal cortex, the area that governs impulse control and the ability to envision the consequences of one's actions. This is akin to a car having an accelerator but no brakes and may explain, in part, why some adolescents' impulsivity leads them to become involved in risky behaviors.

Beyond the structural alterations that are occurring, many studies indicate that the adolescent brain works differently than that of an adult. By use of functional MRI (fMRI), a technique that measures hemodynamic responses to neural activity, Galvan and colleagues⁹ have examined an area of the brain called the nucleus accumbens. Activity in this area correlates with the anticipation of a positive consequence of a risky behavior and the likelihood of engaging in such behaviors. These investigators found that adolescents activated the nucleus accumbens to a greater degree than did children or adults, an observation that adds to our understanding of risk-taking behavior.⁹ Studies employing fMRI also illustrate variations in the ways adolescents and adults process social emotions, like embarrassment, guilt, or shame, that require one to consider others' feelings or beliefs. In a study by Burnett and colleagues,¹⁰ fMRI scanning was performed while subjects were asked to think about scenarios designed to evoke various emotions. Adolescents and adults differed with respect to areas of the medial prefrontal cortex that were activated.¹⁰ Burnett and Blakemore¹¹ conclude from the results of this and other studies that adolescents may process information less efficiently and, as a result, have not fully mastered certain social tasks and situations.

Implications of the Metamorphosis

The physical alterations accompanying puberty may have profound effects on adolescents. Uncertainty about the changes in their bodies and questioning whether one is normal is common. Parents can be advised to prepare their child for what is to come, and health care professionals can serve as a source of information and offer reassurance when appropriate. The latter may be particularly important for adolescents in whom the pace of pubertal progression, either slower or quicker, differs from that of their peers.

Because brain maturation is not complete until the third decade, it may be wise to reconsider our role as parents and

health care professionals. Although they may look like adults, adolescents do not think like adults. For this reason, many young people will benefit from continued, albeit progressively diminishing, support from parents, adults, and institutions that provide guidance and help them learn appropriate skills and adult behaviors. As health care professionals, we should regularly inquire about our patients' interests, supports, and strengths, as well as about any involvement in risky behaviors. Beyond this, our efforts at adolescent health promotion, when possible, should be developmentally appropriate. In the case of preventing tobacco use, for example, since adolescents may not fully appreciate the consequences of their actions, simply offering information about the potential haz-

ards and recommending avoidance will often be insufficient. Rather, public policy measures, including the restriction of sales, advertising, and use, likely will be more effective.

Fifty years ago, Dr. J. Roswell Gallagher, the founder of adolescent medicine, wrote, "Adolescents are different, and it is clearly desirable to think about them in different terms than one does of a little child or an adult."^{12(ix)} In view of recent information about brain development during adolescence, this observation is remarkably prescient and remains valid. The adolescent metamorphosis is an extraordinary phenomenon that presents both challenges and opportunities for parents and health care professionals. **NCMJ**

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